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Review Article

Isokinetic testing of the shoulder rotator muscles of older individuals with shoulder pathology: An integrative review

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Abstract.
BACKGROUND: Shoulder pathology is common, particularly in older adults. This pathology often involves the muscles of the shoulder, particularly those of the rotator cuff. Although there are many procedures for measuring muscle weakness and imbalance of the shoulder rotator muscles, isokinetic dynamometry is probably considered the gold standard.
OBJECTIVE: To describe the use and findings of isokinetic testing of the shoulder rotator muscles in patients with shoulder disorders.
METHODS: A PubMed search was performed using the string "isokinet* AND rotator cuff." Thereafter, a secondary hand search was conducted. Original articles that reported isokinetic measures of the shoulder rotators in older patients with orthopedic shoulder disorders were identified, summarized, and critically appraised.
RESULTS: Thirty-four relevant articles were found. The articles largely support the validity, reliability, and responsiveness of isokinetic strength measures of shoulder rotation strength in patients with shoulder pathology.
CONCLUSIONS: The literature provides support for the isokinetic measurement of rotator muscle performance in patients with shoulder pathology. However, it is not always practical in the clinical setting.

Keywords: Isokinetics, muscle strength, rotator cuff, shoulder disorders, clinimetrics

1. Introduction

Shoulder pain and dysfunction are common, particularly among older adults [1]. Pathology of the shoulder rotator muscles, most notably those of the rotator cuff (RTC) is often responsible for this pain and dysfunction [2]. Injuries of the RTC account for numerous physician and physical therapy visits [1,3]. Muscle strength testing is a fundamental component of the assessments conducted during these visits [4].

Although there are a number of ways in which strength of the shoulder rotator muscles can be assessed, isokinetic testing is considered by many to be the gold standard. The purpose of this review is to describe isokinetic testing procedures applicable to the shoulder rotator muscles, and findings of the procedures, among older adults with shoulder pathology.

2. Methods

Potentially relevant articles were identified by a search of PubMed on March 4, 2019. The search string used was "isokinet* AND rotator cuff." A hand-search was also conducted. Article titles and abstracts, and where warranted full text, were examined to determine whether articles identified by the searches addressed the isokinetic testing of the shoulder internal and/or external rotator muscles in patients with orthopedic shoulder pathology. In addition to the aforementioned, inclusion required that an article focused on participants over 50

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years of age. To be comprehensive, and in acknowledgement of the impact of the RTC on overall shoulder strength and function [5], the results of the isokinetic testing of other shoulder motions (e.g., flexion) were included when provided. Articles were excluded if they were reviews, written in languages other than English, conducted on only healthy individuals or on patients with primarily neurologic conditions such as stroke, or did not provide procedural specifics or quantitative findings.

Results were collated and summarized in a table. The Table included information about participants (country of origin, number, shoulder pathology, and age), testing procedures, and findings relative to clinimetric properties.

3. Results and discussion

The PubMed search identified 148 potentially relevant articles published since 1985. An additional 5 articles were identified by hand searches. After applying the inclusion and exclusion criteria to the title and abstract, 81 articles were identified as potentially relevant. From these, 34 articles were found to be appropriate for inclusion. The main reasons for exclusion were the use of only young and/or healthy participants or incomplete data. Relevant information from included articles is summarized alphabetically by author in the Table [6–39].

The Table shows that isokinetic dynamometers have been used extensively to measure strength in individuals with shoulder pathology. Studies addressing isokinetic testing of shoulder rotation strength have been conducted in at least 13 different countries, but testing is reported most widely in the United States, followed by Italy, and South Korea. The mean age of individuals participating in collated studies ranged from 50.4 to 73 years. The most common pathology noted was RTC tears with only 3 studies focused on some other diagnosis (e.g., humeral fracture). Many of these studies incorporated post-surgical measures of shoulder rotation strength. The most common time frame was 12 months post-surgery.

In most studies isokinetic strength was measured with some model of Biodex. However, some model of Cybex was used in over 10 studies. Two other brands of isokinetic dynamometer were used in a few studies. Isokinetic testing was carried out at 8 different velocities between 60°/s and 360°/s, but 60°/s was by far the most commonly reported speed. The test position most frequently used was the modified neutral which incorporates approximately 45° of abduction and 30° of flexion at the shoulder; however, testing with the shoulder in 90° of abduction was also common.

The overall validity of isokinetic testing is generally supported by findings of consistently greater peak torque in men than in women [23,28], in younger compared with older individuals [30], in the uninvolved than in the injured shoulder [11,15], and in control groups than in patients with shoulder pathology [11,22].

The most frequently encountered outcome measure across studies was the Constant-Murley Score (CMS) [6,9,11–13], with most studies showing a fair to high correlation between peak torque and overall shoulder function as measured by the 100-point CMS [40].

The validity of isokinetic testing for patients with RTC pathology is supported by the consistent finding of inverse correlations between peak torque and fatty degeneration in the rotator cuff [14,25,26,38]. The utility of isokinetic testing for detecting grades of RTC tears or partial tears is inconsistent [7,10,14,18,24,26,30]. Isokinetic testing is more accurate in diagnosing complete tears of the RTC [18,23,24,26].

We found two studies examining the test-retest reliability of peak torque measurements. The reliability coefficients (ICCs) reported in the studies were all 0.85 or higher [19,22].

Responsiveness is represented by changes in peak torque over time. Relevant changes in patients with RTC lesions include differences in torques measured before and after surgery [11,20,30–32,39] or before and after conservative treatment [8,21]. After surgery there is an initial decrease in peak torque (for approximately 3 months) followed by steady increases thereafter [9,11,20,31]. However, the influence of rehabilitation programs on recovery was not sufficiently described in most studies with some showing continued deficits for certain motions for up to 2 years after surgery [19,27,34,36] while others showed no significant difference after 12–48 months [11,17,20,23,33,34]. Likewise, the evidence supports an increase in peak torque after conservative treatment [8,9].

The findings of this review should be interpreted with caution as there is considerable variability between studies in testing velocities, positions of the participants' bodies and the upper extremity, movements performed, comparison groups, time frames, and operative procedures. Strength comparisons included side to side, control group, the injured extremity at different time frames, or some combination of these. However, measurements of strength utilizing bilateral comparisons

Table 1
Summary of studies describing the isokinetic measurement of strength in chronic obstructive pulmonary disease

Study	Participants	Procedures	Findings
Alta et al. (2014) [6]	Dutch undergoing total ($n = 18$, mean age = 69 y) or reverse total ($n = 12$, mean age = 71 y) shoulder arthroplasty.	Biodex System 3 dynamometer measured shoulder abduction, adduction, external & internal rotation strength (PT) @60°/s, 21 months post-op for reverse & 35 months post op for total shoulder arthroplasty.	Validity: strength after total shoulder arthroplasty SGNF > strength after reverse arthroplasty. Reverse arthroplasty post-op external rotation strength correlated with CMS activity, mobility, and strength subscales ($r = 0.69$–0.77). Total shoulder post-op abduction, adduction & internal rotation strength correlated with CMS post op strength subscale score ($r = 0.56$–0.84).
Analan et al. (2015) [7]	Turks with rotator cuff lesions treated with true ($n = 11$, mean age = 52.9 y) or sham ($n = 11$, mean age = 57.1 y) ultrasound.	Biodex System 3 dynamometer measured shoulder external & internal rotation strength (PT) @60°/s & 180°/s, 20 days after beginning therapy.	Validity: shoulder strength not SGNF correlated with rotator cuff pathology grade. Responsiveness: no SGNF difference in strength between real & sham ultrasound.
Baydar et al. (2009) [8]	Turks with conservatively treated full-thickness supraspinatus tears ($n = 20$, mean age = 60.9 y).	Cybex Norm dynamometer measured bilateral shoulder abduction, external & internal rotation strength (PT) @60°/s & 180°/s, before and 6 months after treatment.	Responsiveness: strength of all motions of involved side ↑ SGNF after treatment.
Bigoni et al. (2009) [9]	Italians undergoing 1 of 2 different types of arthroscopic repair for full-thickness rotator cuff tear ($n = 50$, mean age = 59 y).	Technogym Rev 7000 VX dynamometer measured shoulder external & internal rotation strength (PT) @60°/s, pre-op, 3, 6, & 12 months post-op.	Responsiveness: strength on the operated side ↑ SGNF in both groups following surgery. Strength return in tendon to bone technique SGNF > side to side repair.
Colliver et al. (2016) [10]	Australians with full-thickness supraspinatus tears who underwent acromioplasty ($n = 60$, mean age = 58.8 y).	Biodex dynamometer measured concentric shoulder flexion, external & internal rotation strength (PT) @60°/s, 16-weeks post-op.	Validity: no SGNF strength difference between subjects with intact tendons, tendinopathy or partial-thickness re-tears.
Cools et al. (2006) [11]	Belgians with full-thickness rotator cuff tears ($n = 24$, mean age = 57.2 y) & healthy controls ($n = 29$, mean age = 56.4 y).	LIDO dynamometer measured bilateral shoulder external & internal rotation strength (PT) @60°/s & 180°/s, pre-op & 18 months post-op.	Validity: pre-op strength on the operated side of the rotator cuff tear group @60°/s SGNF < uninvolved side & controls; external rotation strength on operated side @180°/s SGNF < uninvolved side. CMS correlated with pre-op strength ($r = 0.57$–0.82). Responsiveness: strength @60°/s SGNF ↑ on the operated side pre- to post-op. No SGNF side or group differences @18 months post-op.
Costantino et al. (2014) [12]	Italians with proximal humerus fractures ($n = 46$, mean age = 63.04 y) after open reduction internal fixation & physical therapy.	Biodex System 3 dynamometer measured bilateral concentric shoulder flexion & extension strength (PT) @180°/s & 300°/s; & external & internal rotation strength (PT) @60°/s & 240°/s, 12–60 months post-op.	Validity: SGNF correlation between CMS & all peak torque parameters ($r = 0.40$–0.50).
Davidson and Rivenburgh (2000) [13]	Americans with full-thickness rotator cuff repairs ($n = 63$, mean age = 62.5 y).	Lido Active dynamometer measured Ⓑ shoulder flexion, extension, external & internal rotation strength (PT) @60°/s & 360°/s, pre-op & 6, 12- & 24-months post-op.	Validity: SGNF ↓ strength with ↑ tendon tension on the operated side.
Demirors et al. (2009) [14]	Turks who underwent open rotator cuff repair ($n = 25$, mean age intact repairs = 53.7 y & failed repairs = 63.7 y).	Cybex 770 Norm dynamometer measured shoulder abduction, adduction, flexion, extension, external & internal rotation strength (PT) @60°/s, 120°/s & 180°/s, 32 months post-op.	Validity: SGNF correlation between tear type & extension strength at all velocities & internal rotation @120°/s ($r = 0.32$ –0.42). Extension (@60°/s & 180°/s) & internal rotation strength (@120°/s) SGNF ↓ in failed repairs; internal rotation strength SGNF ↓ @60°/s & 120°/s in those with ↑ fatty degeneration.

Table 1, continued

Study	Participants	Procedures	Findings
Ellenbecker et al. (2006) [15]	Americans with full thickness rotator cuff tears ($n = 37$, mean age = 57.3 y) who underwent arthroscopically assisted mini-open repair.	Cybex 6000 dynamometer measured bilateral shoulder external & internal rotation strength (PT) @90°/s, 210°/s & 300°/s, 12 weeks post-op.	Validity: operated side external rotation was ↓ 5–7% at all speeds & internal rotation ↑ 6–11% @210°/s & 300°/s compared with uninvolved side.
Ghandour et al. (2019) [16]	Egyptians with repaired complete rotator cuff tears who wore either a pouch arm sling ($n =$ 55, mean age 50.8 y) or abduction brace ($n =$ 51, mean age=50.4 y).	Biodex System 3 dynamometer measured bilateral shoulder external & internal rotation strength (PT) @60°/s, 120°/s & 180°/s, 1-year post-op.	Validity: no SGNF strength difference between sides at any velocity. CMS score & PT SGNF correlated at each velocity ($r = 0.84$–0.92).
Hartsell (1993) [17]	Canadians receiving rotator cuff repair with acromioplasty ($n = 9$, mean age = 60.8 y).	Cybex II dynamometer measured bilateral shoulder external & internal rotation strength (PT) in neutral & 90° abduction @60°/s & 120°/s, 2–4 years post op.	Validity: PT at slower velocities SGNF > faster velocities. Operated side internal rotation strength 9% > uninvolved side. No SGNF external rotation strength difference between sides or test positions.
Itoi et al. (1997) [18]	Japanese with unilateral partial- ($n = 10$, mean age = 56 y) or full-thickness supraspinatus tears ($n =$ 10, mean age = 56 y).	Cybex 340 dynamometer measured bilateral shoulder abduction, adduction, external & internal rotation strength (PT) & total work @60°/s & 180°/s, before & after lidocaine injection.	Validity: after involved side injection abduction & external rotation strength remained SGNF < uninvolved side in those with full-thickness tears but not partial tears. No SGNF correlation between tear size & PT.
Keen et al. (2006) [19]	Americans after massive rotator cuff tear reconstruction using long head of triceps brachii ($n = 14$, mean age = 63.1 y).	Biodex Multi-Joint System 3 measured bilateral shoulder external & internal rotation & elbow extension strength (PT) @60°/s & 120°/s, 2 years post-op.	Reliability: test-retest ICC ⩾ 0.85 (no time interval given). Validity: involved side external rotation & elbow extension strength SGNF < uninvolved side.
Kirschenbaum et al. (1992) [20]	Americans with rotator cuff tears treated surgically ($n = 25$, mean age = 62 y).	Cybex II dynamometer measured bilateral shoulder external rotation, flexion, & abduction strength (PT) @90°/s, pre-op, 6- & 12-months post-op.	Validity: no side to side differences @12 months. Responsiveness: strength @6-month post-op SGNF > pre-op; & 12-month post-op SGNF > 6-month for all motions.
Krischak et al. (2013) [21]	Germans with unilateral rotator cuff tears treated conservatively ($n = 22$, mean age = 56.4 y) or with home program ($n = 16$, mean age = 53.7 y).	Biodex Multi-Joint System 3 dynamometer measured shoulder abduction, adduction, external & internal rotation strength (PT) @60°/s & 120°/s, before & after 2 months of treatment.	Validity: after treatment no SGNF difference between groups for pain, CMS, range of motion, or strength.
Land et al. (2016) [22]	Australians with subacromial impingement syndrome ($n = 51$, mean age = 51.2 y) or asymptomatic controls ($n = 51$, mean age = 50.8 y).	Cybex Humac Norm dynamometer measured shoulder external & internal rotation strength (PT) @60°/s & 120°/s.	Reliability: control group PT ICC = 0.95 (no time interval given). Validity: concentric external & eccentric internal rotation strength @60°/s & eccentric external & internal rotation @120°/s in impingement group with dominant arm involvement SGNF < control.
Leroux et al. (1995) [23]	French patients with subacromial impingement syndrome who underwent anterior acromioplasty ($n = 16$, mean age = 51 y).	Biodex Multi-Joint system dynamometer measured bilateral shoulder external & internal rotation strength (PT) @60°/s & 180°/s, 44.5 months post-op.	Validity: no SGNF strength difference between sides. Rotation strength in men SGNF > women. SGNF correlation in full thickness tear group between internal to external rotation ratio & lesion size ($r = 0.66$).
Lubiatowski et al. (2013) [24]	Polish patients following rotator cuff repair ($n =$ 111, mean age = 56 y).	Biodex System 3 dynamometer measured shoulder external & internal rotation strength (PT) @90°/s, 180°/s, 270°/s, & 360°/s, 39.5 months post-op.	Validity: external rotation strength, average work & power in complete re-tear group SGNF < partial & no re-tear groups @90°/s & 180°/s.

Table 1, continued

Study	Participants	Procedures	Findings
Oh et al. (2009) [25]	South Koreans with shoulder pain with (n = 228, mean age = 61.3 y) & without (n = 138, mean age = 54.1 y) full-thickness rotator cuff tears.	Biodex System 3 dynamometer measured bilateral shoulder abduction & external rotation strength (PT). Velocity not provided.	Validity: SGNF correlations between serum vitamin D & bilateral abduction (r = 0.14–0.21) & external rotation (r = 0.25) strength in both groups.
Oh et al. (2010) [26]	South Koreans with unilateral rotator cuff tears (n = 86, mean age = 59.7 y) treated surgically.	Biodex System 3 dynamometer measured bilateral shoulder abduction, external & internal rotation strength (PT) & total work @60°/s, pre-op & at least 12 months post-op.	Validity: pre-op peak torque SGNF correlated with manual muscle testing scores (r = 0.13–0.46), tear size (r = 0.27–0.41) & fatty degeneration (r = 0.24–0.44). Post-op total work deficit SGNF greater in those with ↑ fatty degeneration & larger tears. Pre- & post-op peak torque deficits SGNF correlated with post-op cuff integrity (r = 0.09–0.50).
Oh et al. (2010) [27]	South Korean men (n = 81, mean age = 60 y) and women (n = 96, mean age = 60 y) with full thickness rotator cuff tears who underwent repair.	Biodex System 3 dynamometer measured bilateral shoulder abduction, external & internal rotation strength (PT) @60°/s, at least 1-year post-op.	Validity: operated side strength SGNF < uninvolved side for all motions. Strength SGNF ↓ & re-tear rate ↑ as subjects aged.
Petriccioli et al. (2016) [28]	Italians with 1 of 2 types of latissimus dorsi transfer (n = 8 & n = 25, mean age = 57.9 y) for posterosuperior rotator cuff tear.	Biodex System 3 dynamometer measured bilateral shoulder flexion, extension, external & internal rotation strength (PT) @210°/s, 35.7 months post-op.	Validity: flexion & external rotation strength in men SGNF > women & correlated with CMS in both surgical groups (r = 0.68 & 0.47).
Pilge et al. (2012) [29]	Germans who underwent rotator cuff repair (n = 30, mean age = 62 y) with a mini-open technique.	Cybex-Isokinetic dynamometer measured bilateral shoulder abduction, flexion, external & internal rotation strength (PT) @60°/s, 37 months post-op.	Validity: no SGNF difference in strength in patients with or without osteolytic changes in surgical bio-anchors.
Porcellinni et al. (1996) [30]	Italians with rotator cuff tears (n = 30, mean age = 58 y) who underwent surgery.	Lido dynamometer measured bilateral shoulder external & internal rotation strength (PT) @60°/s, 3,6, & 12 months post-op.	Validity: recovery of strength SGNF correlated with age (r = −0.35 & 0.56) & tear size (r = −0.5& 0.68). Responsiveness: recovery of strength SGNF correlated with time (r = 0.58–0.68).
Rhee et al. (2018) [31]	South Koreans with full-thickness rotator cuff tears receiving continuous ropivacaine (n = 33, mean age = 62.3 y), controlled infusion (n = 30, mean age = 57.5 y), or an intravenous patient-controlled analgesia/ interscalene block (n = 55, mean age = 62.8 y).	Biodex System 3 dynamometer measured bilateral shoulder abduction, external & internal rotation strength (PT), pre-op & 1-year post-op.	Responsiveness: strength SGNF ↑ for all motions in all groups pre-op to 1-year post-op.
Rokito et al. (1999) [32]	Americans with large or massive chronic rotator cuff tears (n = 30, mean age = 57 y) who underwent surgery.	Biodex dynamometer measured bilateral shoulder flexion, extension, abduction, adduction, external & internal rotation strength (PT) @60°/s, pre-op & 12 months post-op.	Responsiveness: post-op flexion, abduction & external rotation strength of operated side SGNF > pre-op.
Verdano et al. (2013) [33]	Italians with full-thickness rotator cuff tears who underwent arthroscopic repair (n = 42, mean age 59).	Biodex dynamometer measured bilateral shoulder flexion, extension, external & internal rotation strength (isometric, isotonic & PT), total work, & average power @90°/s, 12 months post-op.	Validity: no SGNF difference between sides for any condition.

Table 1, continued

Study	Participants	Procedures	Findings
Walmsley and Hartsell (1992) [34]	Canadians who underwent rotator cuff repair (n = 24, mean age = 58.3 y).	Cybex II dynamometer measured bilateral shoulder flexion, extension, abduction, adduction, external & internal rotation strength (PT) @60°/s, 120°/s & 180°/s, at least 1-year post-op.	Validity: operated side flexion strength at all speeds & external rotation @60°/s & 180°/s SGNF < uninvolved side. No SGNF difference for extension, abduction, adduction or internal rotation at any speed.
Wang et al. (2015) [35]	Australians after arthroscopic supraspinatus repair who received (n = 30, mean age = 59.8 y) or did not receive (n = 30, mean age = 58.4 y) platelet-rich plasma injections.	Biodex dynamometer measured bilateral shoulder external rotation & flexion strength (PT) & total work @60°/s & 90°/s, 16 weeks post-op.	Validity: no SGNF differences between groups for strength or total work.
Yen (2005) [36]	Canadians who underwent open rotator cuff repair (n = 14, mean age = 58 y).	Cybex II dynamometer measured bilateral shoulder flexion, abduction & external rotation strength (PT) @60°/s, 120°/s, & 180°/s, 2 years post-op.	Validity: involved side abduction strength @120°/s & external rotation & flexion strength @ all speeds SGNF < uninvolved side.
Yoon et al. (2013) [37]	South Koreans with partial- (n = 96, mean age = 60.8 y) or full-thickness (n = 37, mean age = 60.5 y) subscapularis tears & controls (n = 179, mean age = 54.5).	Biodex System 3 dynamometer measured bilateral shoulder internal rotation strength (PT) @60°/s, pre-op.	Validity: the lift off test, internal rotation lag sign & belly press test are SGNF correlated with internal rotation strength deficits (r = 0.70–0.95).
Yoon et al. (2018) [38]	South Koreans who underwent full-thickness rotator cuff repairs (n = 203, mean age = 61.3 y).	Biodex System 3 dynamometer measured bilateral shoulder abduction, external & internal rotation strength (PT & total work) @60°/s, pre-op.	Validity: external rotation & abduction strength SGNF ↓ in those with a "+" tangent sign. Supraspinatus, infraspinatus, and external rotation occupational ratios SGNF correlated with abduction, external rotation &internal rotation peak torque, respectively (r = 0.17–0.29).
Zuckerman et al. (2000) [39]	Americans with complete supraspinatus & infraspinatus ruptures who underwent hemiarthroplasty (n = 15, mean age = 73 y).	Biodex dynamometer measured shoulder flexion, abduction & external rotation strength (PT) pre-op. 6/15 shoulders also tested 28.2 months post-op.	Responsiveness: post-op flexion (not external rotation or abduction) strength on operated side SGNF > pre-op.

SGNF = significant, significantly; CMS = Constant-Murley Score; SLAP = Superior labrum anterior posterior tear; SPADI = Shoulder Pain and Disability Index; ICC = intraclass correlation coefficient; r = correlation coefficient; y = years, PT = peak torque.

did not always specify the criteria for identifying significant strength deficits. For instance, it may be expected that the dominant upper extremity is 10–15% stronger than the non-dominant upper limb [41] and statistical difference may not equate with clinical significance. It should also be noted that while the focus of this paper was intended to be on older adults, most of the studies involved the young-old. The practicality and utility of isokinetic testing of the shoulder rotator muscles of middle-old and oldest-old remains largely unexplored.

Finally, a single bibliographic database was used. While it is doubtful that the inclusion of additional databases would have markedly altered the results, such an expansion may have added to the evidence for the conclusions presented. A more systematic review may have also allowed for a meta-analysis of some variables and for a quality assessment of included articles.

4. Conclusions

Muscular weakness and imbalance of the RTC and surrounding muscles are important symptoms of shoulder pathology that can be objectively measured with isokinetic testing. This review supports the reliability, validity, and responsiveness of isokinetic measurements of rotator muscle performance in young-old patients with shoulder pathology. However, it is not always practical in the clinical setting

Conflict of interest

The author declares no conflict of interest.

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